A New Recent Sclerosponge from Ngargol, Palau Islands and Its Fossil Relatives

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Kei Mori

ABSTRACTS

The skeleton of *Tabulospongia horiguchii*, n. gen. and n. sp. (Porifera) is composed of high magnesium calcite, organic materials and siliceous spicules. Based on the new genus, the new family Tabulospongiidae in the Order Tabulospongida Hartman and Goreau, 1975 is proposed. It differs from the Order Ceratoporellida by having calcitic skeleton. The group of the Mesozoic Acanthochaetetidae Fischer, 1970, is not identical with the Recent calcitic sclerosponges. Extinct stromatoporoids can be distinguished in several aspects from the sclerosponges as described in the text. Their skeletal characters may be of a distinct group among the Coelenterata or of natures transitional between the Porifera and Coelenterata.

INTRODUCTION

The discovery of Recent sclerosponges by Hartman (1969) and Hartman and Goreau (1966, 1970a, b, 1972 and 1975) has stimulated the studies not only on this new group of sponges but also on the taxonomic positions of extinct stromatoporoids and chaetetids. Following this discovery, the first report of a fossil sclerosponge was by Kaźmierczak (1974) from the Lower Cretaceous of the Slovakian Tatra Mountains. Kaźmierczak and Hillmer (1974) reported that the genus *Neuropora* which was formerly considered to be a bryozoa or a stromatoporoid (Brood, 1971) is a sclerosponge. Thus our knowledge on the fossil and Recent sclerosponges has progressed rapidly.

Two specimens of a Recent coralline sponge from Ngargol, Palau Islands were donated to the author by Dr. M. Horiguchi (Department of Earth Sciences, Saitama University). The locality, as shown in Fig. 1, is situated in lat. 7°20′15″7N and long. 134°27′28″E. They were collected from an underwater sea cave, about 10 m deep. Unfortunately no soft parts of the specimens were available for investigation. However, detailed studies on the skeleton of the samples has revealed that they belong to the Class Sclerospongiae, but differ from the sclerosponges previously described. The skeletons of the sclerosponges here reported are composed of calcite, organic materials and siliceous spicules. They differ from the sclerosponges from Jamaica, Western Atlantic, reported by Hartman (1969) and Hartman and Goreau (1966, 1970a and 1972) by having calcitic skeletons. Recently Hartman and Goreau (1975) reported on the Recent sclerosponges from the Western Pacific, which are composed of calcitic skeletons. They described *Acanthochaetetes wellsi* and proposed a new Order Tabulospongida. The materials here treated are very similar to *A. wellsi* in general characters, but in this paper the author referred *wellsi* and the new species described herein to the new genus *Tabulospongia* excluding both from the *Acanthochaetetes*.

The purpose of the present paper is to describe a new Recent sclerosponge from Ngargol, Palau Islands and to discuss briefly the systematic position of stromatoporoids in relation to sclerosponges.

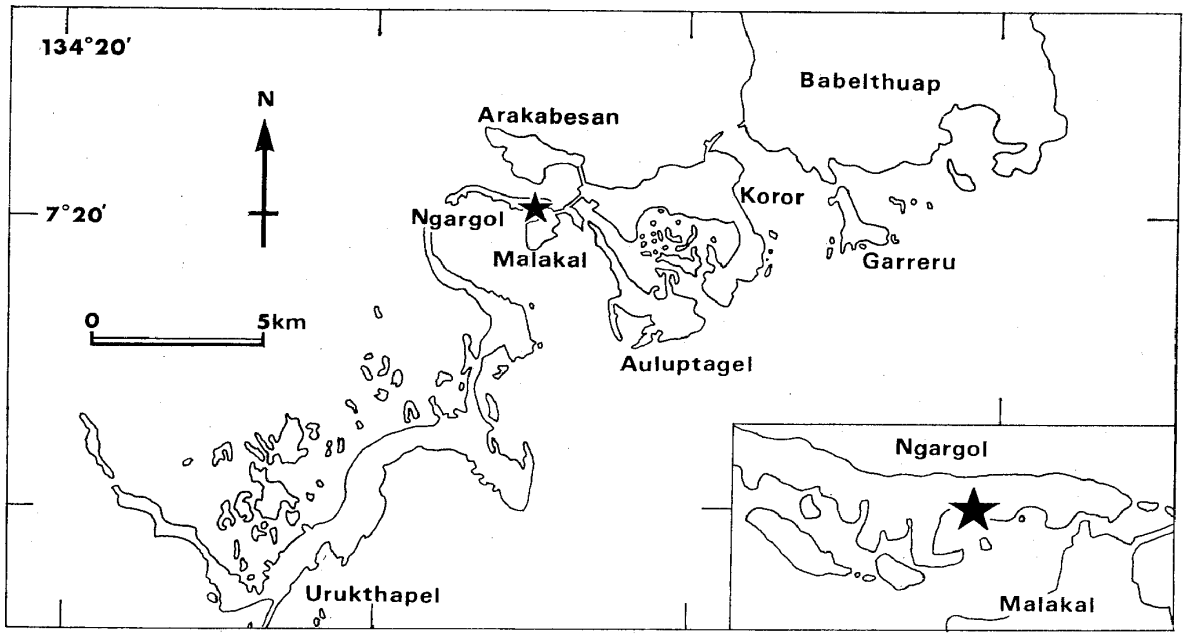

Fig. 1. Index map of the Palau Islands, showing collecting locality of the specimens investigated. (after Mori and Horiguchi, 1975)

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THE MORPHOLOGY OF *TABULOSPONGIA HORIGUCHII* MORI, N. GEN. AND N. SP.

Two specimens of *Tabulospongia horiguchii* Mori, n. gen. and n. sp. are in the collection. The larger specimen (holotype) is massive in shape, 8.6×5.6 cm in diameter at the base and 4.6 cm in maximum height at the middle of the skeletal mass. The basal part of the skeleton is anchored to the substrata by four stem-like peduncles that grow upwards to the expanded base to form a single skeletal mass. At the base, concentric growth lines are well developed. Stellate patterns of depression are well developed on the surface of the skeleton. Their appearance on the surface is more or less similar to that of the astrorhizae in stromatoporoids. They serve as exhalant canals which are common in previously known sclerosponges. Each structure is placed on a mamelon rising to a height of several milimeters. The height of the mamelons is variable. The distances from center

to center of the mamelons vary in general from 6 to 15 mm. In thin sections no stellate structures are morphologically traced in the skeletal elements below the surface. The other specimen (paratype) is small, 2.5×2.5 cm in diameter at the base and 2.4 cm in the maximum height at the middle of the skeleton. Its surface is in most part encrusted by an unnamed hydrozoan.

The skeleton is composed of closely spaced pits, showing honey-comb pattern of structures. The adjacent pits are closely united by thin walls as in Chaetetids. The shape of the pits is variable. It is polygonal in most cases, but some are circular or elliptical in outline. The maximum diameter of the lumens of the pits is 613μ, but in general in the range of 438μ–563 μ and 500 μ on average, measured in 50 larger pits. Very small pits less than 400 μ in diameter are also common. They are young pits arised by intramural offsets. The range of variation in size is continuous. Vertical thin sections show that the walls of the pits continue deep, mostly reaching the base. The maximum thickness of the wall is 88 μ and the thinnest one is 38 μ, generally falling in the range of 50 μ – 62 μ measured in 50 parts of the wall. The surface of the walls is rugged, consisting of small knobs as shown in Pl. 4, fig. 2. Fine skeletal structures of the walls are composed of aggregations of very small needle-like calcite crystals which are randomly oriented. They show consequently lamellar structures as illustrated in Pl. 3, fig. 7. The lumens of the pits are preserved as cavities, not filled secondarily with carbonate substances. There are spines protruded inwards from the wall. They are very common, especially near the mamelons which are the center of the stellate depression.

The base of the living tissue-filled spaces is bounded by tabulae. The tabulae are very thin, subhorizontal or slightly arched upwards. They are generally aligned from one pit to another, occurring at nearly regular intervals. There are two or three tabulae per 2 mm in each pit, ranging from 0.5–1.5 mm apart measured in vertical section. The thickness of the tabulae is 15 μ–30 μ.

Besides the calcite and organic materials, siliceous spicules are found in the pits. There are two types of spicules; megascleres and microscleres. The siliceous megascleres are of fusiform type. They are slightly warped, the tips of which are sharply pointed. The surface of the spicules is smooth without any other modifications. Each megasclere varies from 267 μ to 397 μ in length, mostly falling in the range from 300 μ to 350 μ. The maximum width varies from 5.7 μ to 14.0 μ at the middle of the megasclere. The measurements mentioned above are based on 50 spicules. The direction of the long axis of the megascleres are random in distribution and no regular arrangements have been recognized on the surface of the skeleton. The siliceous microscleres are modified sphaerasters. They are rather uniform in size and shape. The maximum diameter of the microsclere is 27 μ, generally falling in the range of 20 μ–25 μ. It is characteristic that the mega- and microscleres are not incorporated in calcitic skeletons. The microscleres are developed only on the outer surface of the skeleton and not found in the lumens under uppermost tabulae, while the megascleres are rarely observed in the lumens, being deep from the surface.

CHEMICAL COMPOSITION OF THE SKELETON OF *TABULOSPONGIA HORIGUCHII*

The X-ray powder diffraction analyses indicates that the skeleton is calcitic as shown in Fig. 2. Differentiation of the calcitic crystals forming the skeleton was done also by the staining method using Alizarin Red S. The results of the chemical analyses are shown in Table 1. It is concluded that the crystals forming the walls are high magnesium calcite, containing 6.32 weight percent of MgO. Decalcification of the calcitic skeleton by diluted acid has revealed the presence of spicules and organic materials. The treatment by HF after the decalcification proves that the spicules are siliceous. The chemical analysis of the

Table 1. Chemical composition of the skeleton of *Tabulospongia horiguchii* Mori, n. gen. and n. sp.

CaO	47.20 (weight %)
MgO	6.32
Na_2O	0.68
K_2O	0.03
Fe_2O_3	0.03
MnO	tr.
SiO_2	tr.

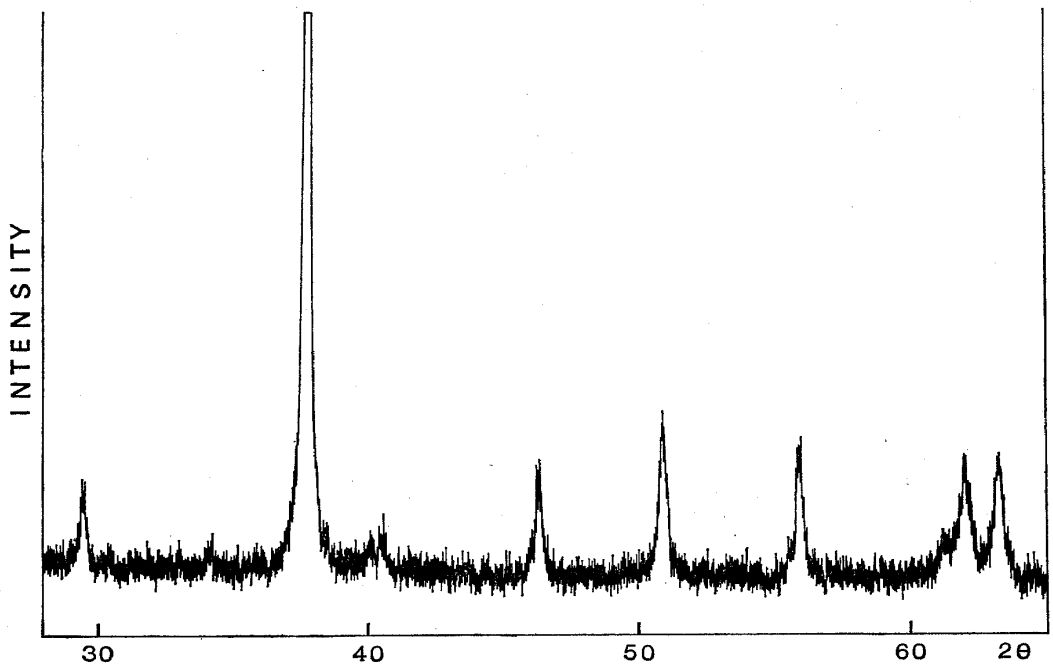

Fig. 2. X-ray powder diffraction patterns of *Tabulospongia horiguchii* Mori, n. gen. and n. sp. FeKα/Mn; 32.5 kV, 20 mA; 1° /min.

skeleton indicates that the spicules are contained in negligible amount of total weight and they do not serve to constitute the main part of the skeleton. Detailed investigation on the organic substances has not been treated in this paper.

ECOLOGY OF *TABULOSPONGIA HORIGUCHII*

The living specimens of *Tabulospongia horiguchii* were collected from a submarine cave, about 10 m deep at the coast of the Island of Ngargol, Palau Islands. They were attached to a hard substratum by stem-like peduncles. The habitat of *T. horiguchii* seems to be the twilight zone. It is worthy to note that the occurrence in depth of *T. horiguchii* is similar to that of *Ceratoporella nicholsoni* (Hickson) from the coast of Jamaica (Hartman and Goreau, 1970a) and *Tabulospongia wellsi* (Hartman and Goreau) from the Pacific (Hartman and Goreau, 1975). Details on the ecology of *T. horiguchii* remain still enigmatic and many specimens with living tissue are needed for further ecological investigation. It is highly probable that many calcitic sclerosponges may live and be widely distributed in the shallow water of the Pacific (see also Hartman and Goreau, 1975).

RELATIONSHIP BETWEEN *TABULOSPONGIA*, N. GEN. AND *ACANTHOCHAETETES*

Hartman and Goreau (1975) described a new Recent sponge *Acanthochaetetes wellsi* from the Pacific. Similarities of general skeletal structures show that the species *wellsi* and *horiguchii* here described belong undoubtedly to the same genus. Hartman and Goreau (*op. cit.*) considered that *Acanthochaetetes* originally proposed by Fischer (1970) based on the Mesozoic fossil species belongs to the Tabulospongida. The species *wellsi* is more or less similar to the Mesozoic ones described by Fischer (1970), Fischer and Laufuste (1972) and Cuif *et al.* (1973) in having similar gross structure, calcitic nature and lamellar microstructure of the skeleton as illustrated by Hartman and Goreau (1975). However, the present author is of the opinion that there is a basic difference between the Recent calcitic sclerosponges and the fossil Acanthochaetetids; the former with siliceous spicules in addition to their calcareous skeleton, while the latter without any siliceous spicules. Lack of evidences of a spicular skeleton in the Acanthochaetetids should be of important taxonomic value, by which it is distinguished from the sclerosponges. Therefore, in the present paper the genus *Acanthochaetetes* is excluded from the Order Tabulospongida, because one of the characteristics of the calcitic sclerosponges is that they secrete siliceous spicules. By this reason mentioned above, a new genus *Tabulospongia* is here proposed for the Recent species *wellsi* described by Hartman and Goreau (1975) and *horiguchii*, n.sp. The family Tabulospongiidae is also newly proposed based on the mentioned genus.

RELATIONSHIP OF *TABULOSPONGIA HORIGUCHII* TO *T. WELLSI*

Tabulospongia horiguchii here studied is very similar to *T. wellsi* from the Western Pacific in general skeletal structures. However the former can be distinguished from the latter by the following characteristics.

(1) Having slightly narrower walls on average.
(2) Having more or less regularly spaced tabulae.

Table 2. Characteristics of the calcareous skeleton of *Tabulospongia horiguchii* and *T. wellsi*. Data on *T. wellsi* are from Hartman and Goreau (1975)

	T. horiguchii	*T. wellsi*
Stellate exhalant canals	present	present
Mamelons	present	present
Concentric growth lines	present	present
Diameter of lumens of pits	generally 438–563; 613 in max. diam.	315 by 300 – 615 by 395
Width of walls	50–62	65–75
Length of spines	50–150	30–180
Max. width of spines	30–40	30–50
Spacing of tabulae	more or less regular; 0.5–1.5 mm apart	irregular; 0.05–0.50 mm apart
Thickness of tabulae	15–30	20–135
Type of megascleres	fusiform type	tylostyle
Length of megascleres	267–397	201–336
Max. width of megascleres	5.7–14.0	2.6–3.9
Type of microscleres	modified sphaeraster; uniform in size and shape	modified spiraster; variable in form
Diameter of microscleres	20 by 20–25 by 25	6 by 5 – 28 by 20
Fine skeletal structures	lamellar	lamellar
Chemical composition of skeleton	high magnesium calcite	calcite
Asexual reproduction	by intramural offsets	by intramural offsets

(3) Megascleres of fusiform type, not of tylostyles.
(4) Microscleres of modified sphaerasters which are rather uniform in size and shape.

Comparison of the calcareous skeleton of *T. horiguchii* and *T. wellsi* is summarized in Table 2.

RELATIONSHIP OF *TABUROSPONGIA HORIGUCHII* TO CERATOPORELLIDS

Among the species of the Order Ceratoporellida described from the Jamaican coast by Hartman (*op. cit.*) and Hartman and Goreau (*op. cit.*), *Ceratoporella nicholsoni* (Hickson) is considered to be most similar to *T. horiguchii* in the following characteristics: (1) skeleton composed of small pits surrounded by common walls; (2) presence stellate exhalant canals on mamelons; and (3) presence of siliceous spicules. However, *T. horiguchii* differs from *C. nicholsoni* by the following features: (1) skeleton consisting basally of high magnesium calcite; (2) presence of siliceous megascleres of fusiform type and microscleres of modified sphaerasters; (3) lumens of the pits not filled in solidly with $CaCO_3$ but preserved as spaces; (4) presence of well developed regularly spaced tabulae; (5) asexual reproduction by intramural offsets; (6) presence of spines developing inwards from pit walls; and (7) lamellar microstructures.

As mentioned above, it is very characteristic that *T. horiguchii* has a skeleton composed of high magnesium calcite and not of aragonite. Its microstructure and shape of spicules are also entirely different from those of *C. nicholsoni*.

DISCUSSION ON SYSTEMATIC POSITION OF STROMATOPOROIDS IN RELATION TO SCLEROSPONGES

Hartman and Goreau (1970a) mentioned that Recent sclerosponges are living representatives of extinct stromatoporoids, being convinced by the presence of spicules in several stromatoporoids, similarities of astrorhizae of the stromatoporoids to exhalant canals of sclerosponges and similarities of gross structures between the two groups. Stearn (1972 and 1975) proposed a new subphylum Stromatoporata in the phylum Porifera, based on comparisons between sclerosponges and stromatoporoids, although he excluded the stromatoporoids from the sclerosponges. Stearn (1972) emphasized that the paleontologist should question whether the stromatoporoids were filter feeders or sought their food by tentacles like a coelenterate, and concluded that the stromatoporoids were basically filter feeders. Thus a hypothesis of an affinity of stromatoporoids to Hydrozoans which has been accepted by many students seems at present to be defensive against their affinity to sponges. However, there are still evidences which can be explained by their affinity to coelenterates as discussed below.

Among the Mesozoic stromatoporoids there exists species such as *Milleporidium steinmanni* Yabe and Sugiyama (Yabe and Sugiyama, 1935, p. 185, pl. 61, figs. 2, 3; pl. 68, figs. 1, 2) which has apparent zooidal tubes with tabulae (Pl. 6, fig. 1). Its gross structures are very similar to those of the Recent genus *Millepora*. Judging from the skeletal structures, it seems reasonable to consider that *M. steinmanni* possessed tentacles. There are apparent transition among the Mesozoic stromatoporoids through the unclear to clear development of zooidal tubes as pointed out by Stearn (1972), although he (Stearn, *op. cit.*) noted that the transition is not complete. It is difficult to separate only *M. steinmanni* from the other species and genera of the Mesozoic stromatoporoids, because the general skeletal structures are very similar to one another and their transition is gradual.

Another evidence for the probable presence of polyps in stromatoporoids is mentioned in *Parallelostroma typicum* (Rosen) from the Ludlovian of Gotland. *P. typicum* is

one of the most important reef builders in the Ludlovian strata of Gotland. The present author (Mori, 1970) noted that no stromatoporoids were obtained from the Ludlovian Burgsvik Beds. However, subsequently he succeeded to find a stromatoporoid, *P. typicum* in the oolitic limestone of the Burgsvik Beds at Uddvide, southern Gotland. It is bell-shaped, 14 cm high and 11 cm wide at the base. It occurred in its probable growth position and at least no evidence of transportation was recognized, because its entire skeleton is well preserved. In addition this stromatoporoid grew under such a condition where ooids were accumulating, because some ooids were found also within its skeleton (Pl. 6, figs. 1–5). If the stromatoporoid, *P. typicum* was a filter feeder like sponges, it would not have been able to live under such an environment as attacked by wave action where ooids were being formed, because a filter feeder lacks sufficient ability to remove the obstacles from the living tissue of the skeleton. The fact that the stromatoporoid could survive in oolites-environment may prove that it had polyps with tentacles like other coelenterates, because only the tentacles possibly with nematocysts could remove ooids falling down continuously on the skeleton by wave action. The ooids found in the cavities of the skeleton of *P. typicum* may indicate that abundant ooids fell suddenly on the stromatoporoid and the amount was beyond the ability of the tentacles to exclude all of them.

Hartman and Goreau (1970a) considered that some stromatoporoids possessed spicules. They showed the supposed pseudomorphs of the spicules in the Carboniferous species *Parallelopora mira* Newell and the Jurassic species *"Stromatopora"japonica* Yabe (=*Parastromatopora japonica* (Yabe)). Kaźmierczak (1974) also noted that several Mesozoic stromatoporoids probably belong to the sclerosponges. Concerning *P. mira*, the opinions of Hartman and Goreau (1970a) were denied by Stearn (1972) and Kaźmierczak (1974). Flügel and Flügel-Kahler (1968) already mentioned that *P. mira* does not belong to the stromatoporoids but to genuine sponges. The presence of calcitic pseudomorphs after siliceous spicules in Mesozoic forms is open to question. Examination of the type materials of the Japanese Jurassic stromatoporoids studied by Yabe and Sugiyama (1935) has convinced the present author that spicules are not present in them. More or less elongated clear areas found in the vertical sections of the skeleton of *Parastromatopora janonica* (Yabe) are interpreted as crystal bundles. Tips of the elongated areas are usually obscure, being unlike elongate pseudomorphs of spicules as in *Murania lefeldi* described by Kaźmierczak (1974). There can be observed circular clear areas at the centers of calcification in fibrous microstructures of the Japanese Jurassic stromatoporoids such as *Parastromatopora japonica* (Yabe), *P. subjaponica* Yabe and Sugiyama, *Epistromatopora torinosuensis* Yabe and Sugiyama and *Milleporidium fasciculatum* Yabe and Sugiyama. They are not considered to be pseudomorphs of spicules, because they are circular in shape as observed both in tangential and vertical sections. The lack of positive evidences of spicules in Paleozoic and Mesozoic stromatoporoids does not support their affinity with sclerosponges (see also Stearn, 1972 and 1975).

Interpretation of function of astrorhizae in stromatoporoids is still controvercial. Hartman and Goreau (1970a) and Stearn (1972 and 1975) supported the hypothesis that astrorhizae of the stromatoporoids were exhalant canals. Although the external appearance of exhalant canals of the sclerosponges and astrorhizae of the stromatoporoids are similar to each other, the function of the latter is enigmatic. As discussed by Kaźmierczak (1974) the presence of tabulae (or dissepiments) in astrorhizal canals of the stromatoporoids seems to be one of the obstacles for considering them as sponges.

The development of latilaminar structures in stromatoporoids is also dissimilar to any group of sponges.

In conclusion, the stromatoporoids differ in many aspects from sclerosponges,

although it is agreeable that there are similarities in gross- and microstructures to some extent between them. It is not overlooked that the stromatoporoids still have several characteristics which are explained by their affinity to coelenterates. The systematic position of the Stromatoporoidea may be related to the Hydrozoa among the phylum Coelenterata or represent a distinct phylum occupying a position between the phyla Porifera and Coelenterata. Much should be studied to confirm the relationship among the stromatoporoids, sclerosponges, hydrozoans and tabulate corals.

SUMMARY OF SYSTEMATICS

Phylum Porifera Grant, 1872

Class Sclerospongiae Hartman and Goreau, 1970

Order Tabulospongida Hartman and Goreau, 1975

Family Tabulospongiidae Mori, n. fam.

Diagnosis: The skeleton is composed of abundant pits, each of which is united by a common wall. On the surface exist stellate patterns that serve as exhalant canals. The composition of the skeleton is calcite. Besides the calcitic skeleton, siliceous spicules are present in the form of fusiform or tylostyles (megascleres) and modified sphaerasters (microscleres). Spines are well developed. Tabulae are well developed. They are regularly or irregularly arranged. The microstructure of the skeleton is lamellar. Asexual reproduction is arised by intramural offsets.
Geological range: Known at present only as Recent.

Genus *Tabulospongia* Mori, n. gen.

Type species: *Acanthochaetetes wellsi* Hartman and Goreau, 1975
Diagnosis: Same as the diagnosis of the family.
Species included: *Tabulospongia wellsi* (Hartman and Goreau) and *T. horiguchii* Mori, n. sp.
Remarks and comparison: See the text.

Tabulospongia horiguchii Mori, n. sp.

Pls. 1–5

Derivation of name: The species is named in honor of Dr. Mankichi Horiguchi, Saitama University, who collected the specimens here described.
Type specimens: Holotype, Reg. no. PA11572; Paratype, Reg. no. PA11573.
Repository: The type specimens are stored in the National Science Museum, Tokyo.
Description: See the text.
Remarks and comparison: See the text.
Geographical distribution: At present known only from the Palau Islands.

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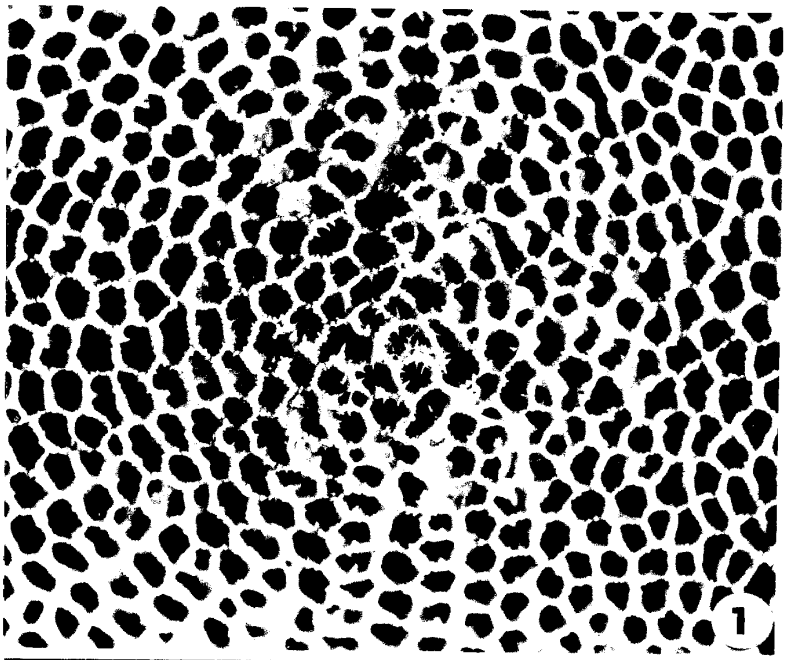
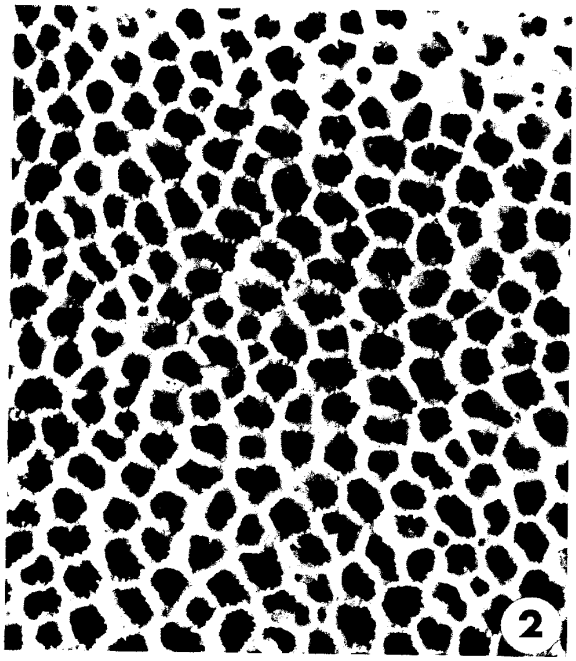
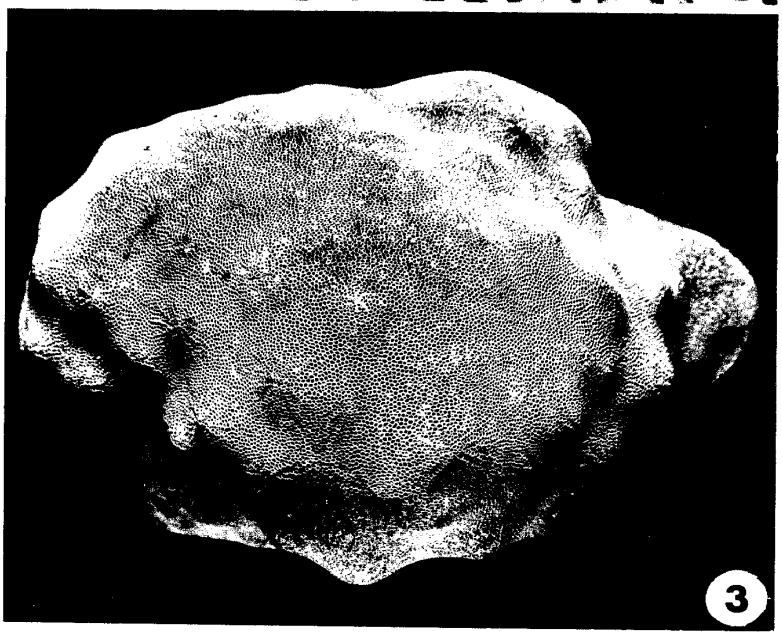
Plate 1

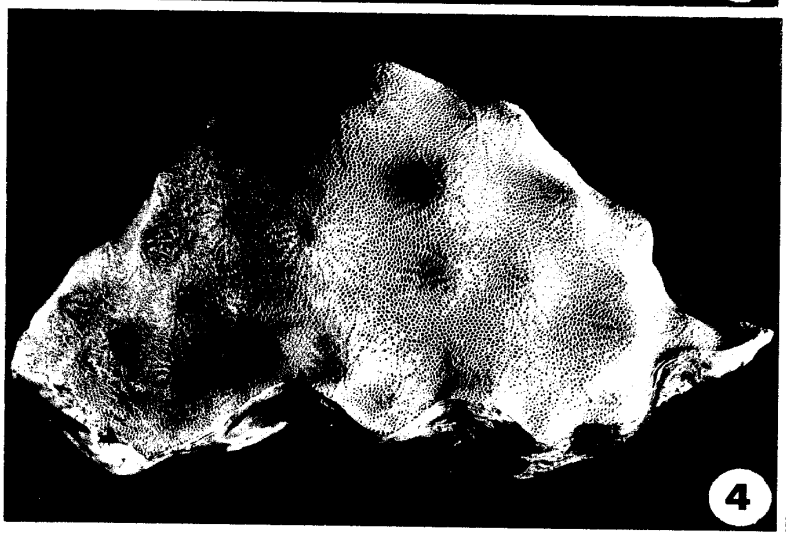
Figs. 1–5. *Tabulospongia horiguchii* Mori, n. gen. and n. sp. Holotype. Reg. no. PA11572.
1 – upper surface of a calcareous skeleton showing pits with many spines at the middle of the photograph which is the center of the exhalant canals, ×10. 2 – same as in Fig. 1, showing pits placed between the centers of the exhalant canals, ×10. 3 – upper surface view, ×1. 4 – side view, showing exhalant canals with mamelons, ×1. 5 – sole surface view, showing concentric growth lines and four stem-like peduncles, ×1.

Figs. 6–7. *Tabulospongia horiguchii* Mori, n. gen. and n. sp. Paratype. Reg. no. PA11573. Calcareous skeleton is encrusted by an unnamed hydrozoan.
6 – side view, ×1. 7 – sole surface view, ×1.









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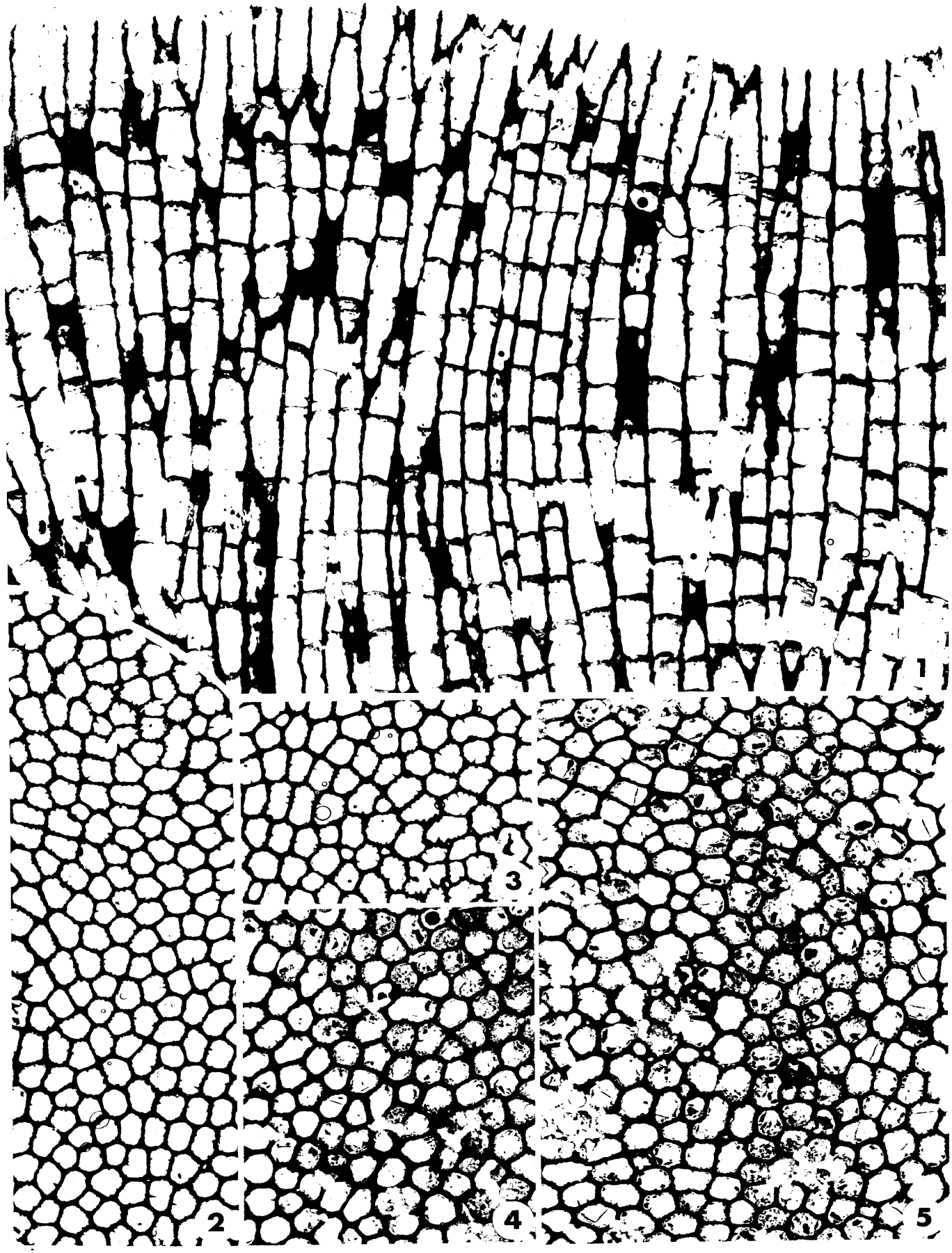

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Plate 2

Figs. 1–5. Thin sections of *Tabulospongia horiguchii* Mori, n. gen. and n. sp.
1 – vertical section, showing walls and more or less regularly spaced tabulae, ×10. 2–3 – tangential sections just below the surface, ×10. 4–5 – tangential sections, 3 cm deep below the surface, ×10.

Plate 3

Figs. 1–7. Thin sections of *Tabulospongia horiguchii* Mori, n. gen. and n. sp.
1 – enlarged view of tangential section of pl. 2, fig. 2, ×50. 2 – tangential section of wall, showing small pit just arised by intramural asexual budding, ×300. 3 – tangential section of wall associated with abundant petal-like microscleres, ×300. 4 – vertical section, showing a junction between wall and a tabula, ×300. 5 – vertical section, showing walls, tabula and spines, ×300. 6 – vertical section, showing top of a wall attached by elongated megascleres and small microscleres, ×300. 7 – vertical section of wall, showing waved lamellar microstructure, ×300.

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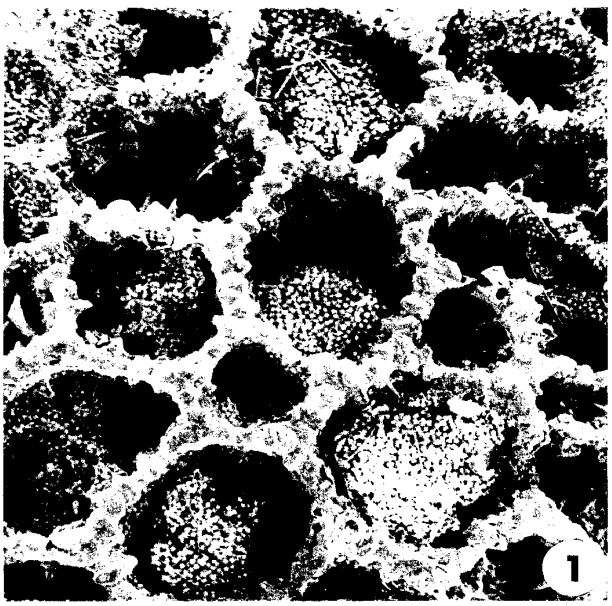

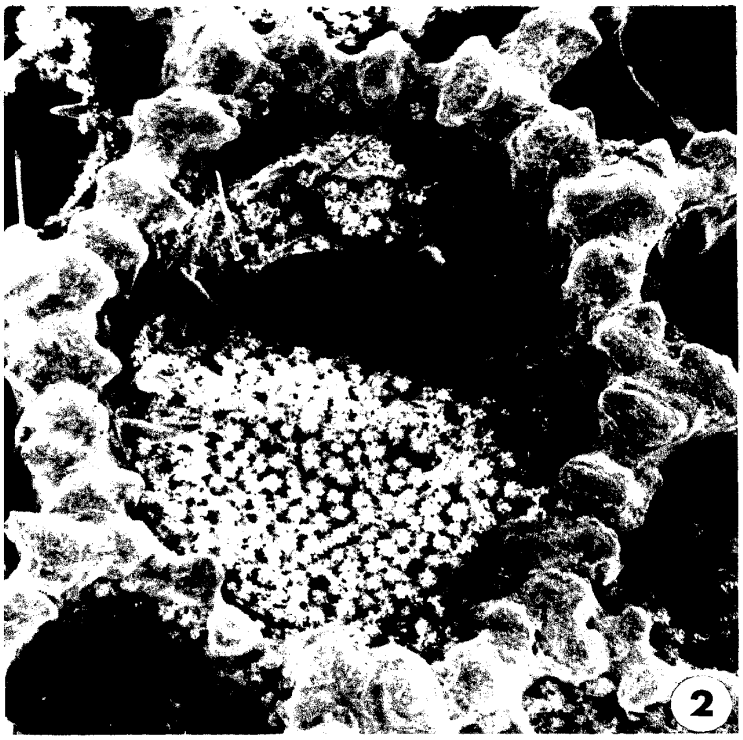

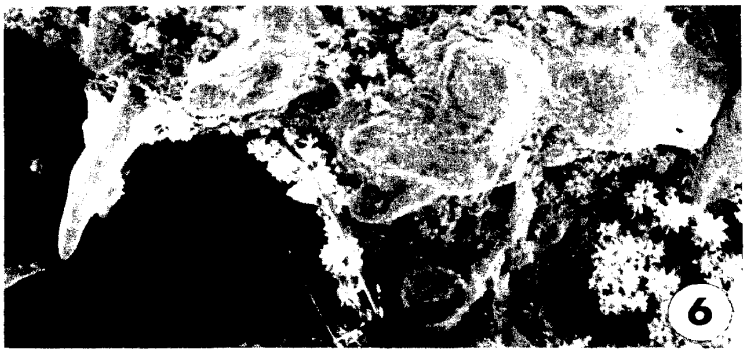

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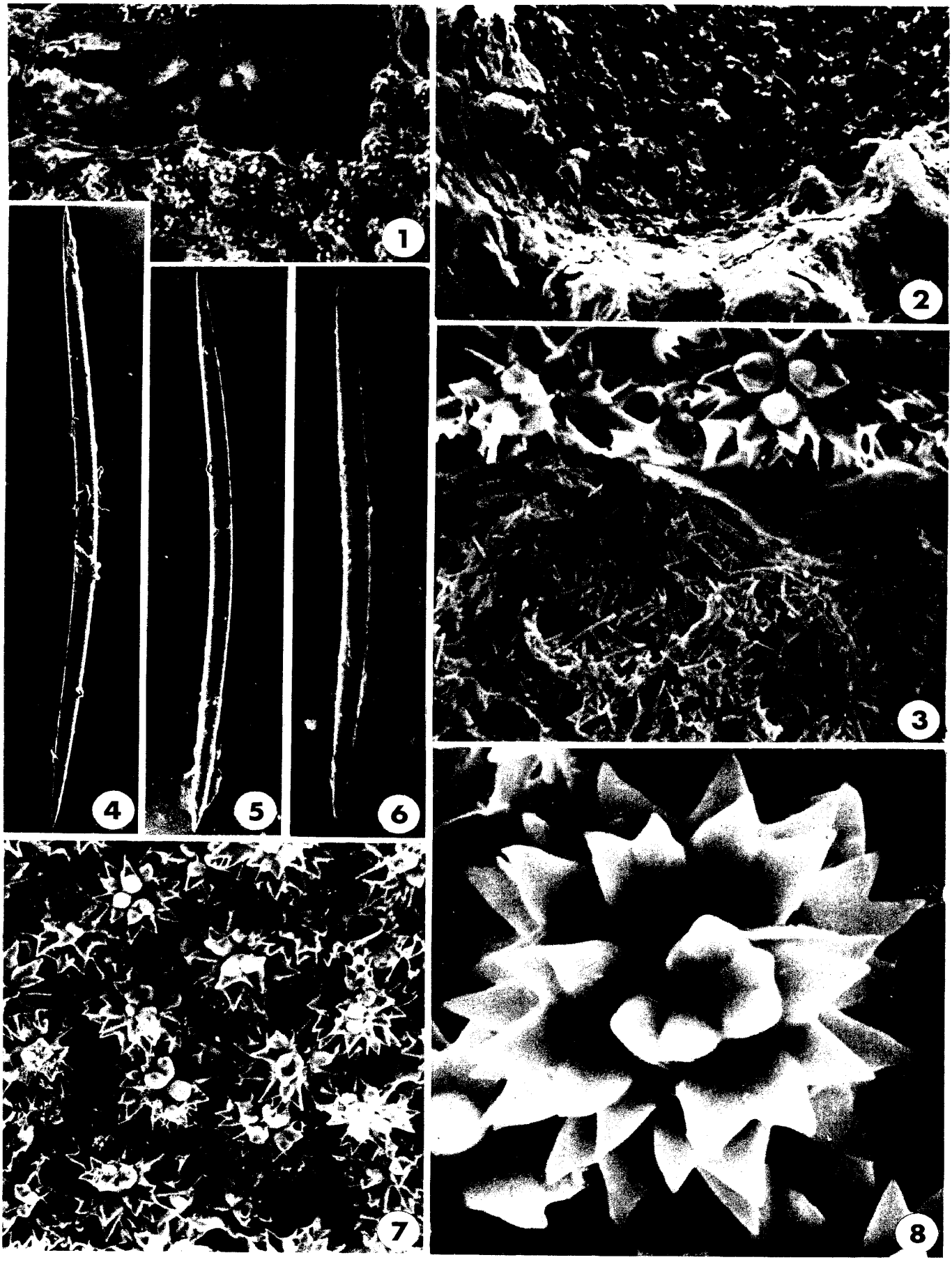
Plate 4

Figs. 1–6. Scanning electron micrographs of *Tabulospongia horiguchii* Mori, n. gen. and n. sp. 1 – surface view, ×50. 2 – enlarged view of a pit in Fig. 1, showing rugged wall, spines and spicules, ×100. 3–4 – inner side view of a lumen of a pit, showing tabulae slightly warped upwards, ×100. 5 – surface view of a lumen of a pit, several spines are projected from wall, ×200. 6 – surface view, showing rugged wall, spine, elongated megascleres and small microscleres, ×200.

Plate 5

Figs. 1–8. Scanning electron micrographs of *Tubulospongia horiguchii* Mori, n. gen. and n. sp.
1 – surface view after etching by diluted acid, note that calcitic walls were destroyed, but microscleres are preserved, ×200. 2 – surface view after etching by HF, note that siliceous microscleres were completely desolved, ×200. 3 – enlarged surface view of wall attached by microscleres, showing microstructures of the skeleton, ×1500. 4–6 – siliceous spicules (megascleres) of fusiform type, ×300. 7 – siliceous spicules (microscleres) of modified sphaerasters, ×750. 8 – enlarged view of a microsclere of a part of Fig. 7, × 3000.



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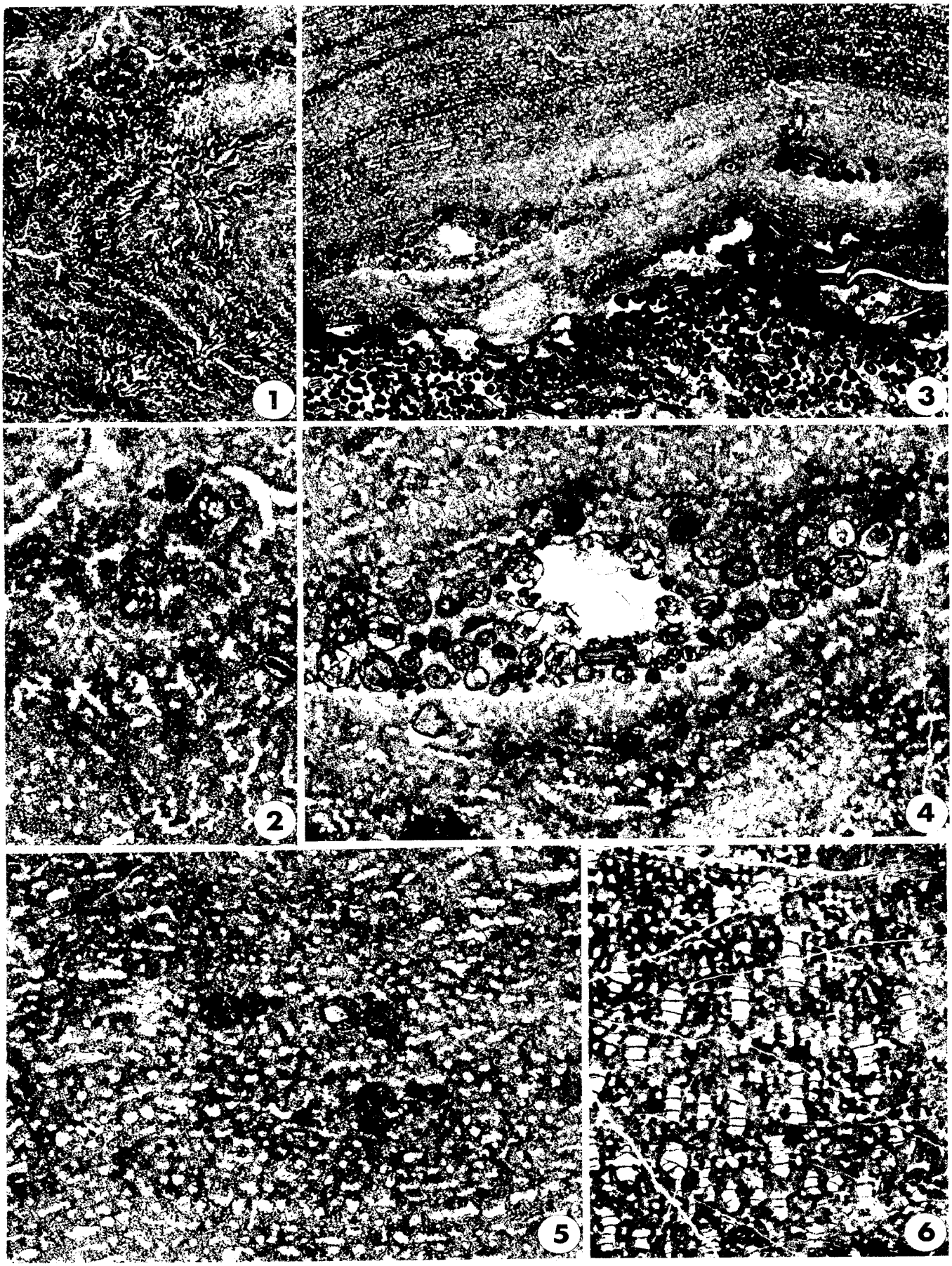

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Plate 6

Figs. 1–5. *Parallelostroma typicum* (Rosen) from the oolitic limestones of the Ludlovian Burgsvik Beds, Gotland, showing ooids in the skeleton.
1 – tangential section of *P. typicum*, ×3. 2 – enlarged view of a part of Fig. 1, ×10. 3 – vertical section of *P. typicum*, ×3. 4 – enlarged view of a part of Fig. 3, ×10. 5 – tangential section of *P. typicum*, ×10.

Fig. 6. Vertical section of *Milleporidium steinmanni* Yabe and Sugiyama from the Japanese Jurassic, showing zooidal tubes, ×10.